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THE MACKEREL

SPAWNING — LARVAL AND POSTLARVAL FORMS
AGE GROUPS — FOOD — ENEMIES

SECOND REPORT

TO THE INTERNATIONAL COUNCIL FOR THE INVESTIGATION OF THE SEA

BY

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EN COMMISSION CHEZ
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COPENHAGUE

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I. Spawning.

The eggs of the mackerel were, as already mentioned in a previous[1] report, first brought to light by G. O. Sars (1869 and 1878)[2]. Their development was described, with illustrations, by J. T. Cunningham, in Vols. I and II of the Plymouth Journal, and in his Handbook (1896, p. 313—317); also by E. W. L. Holt, who studied them in Irish waters (1893, p. 10—19). Further, supplementary information concerning the eggs of the mackerel on the shores of Northern Europe, has been furnished by Heincke and myself (1900, p. 275) and also by me (1907, p. 248), by J. J. Tesch (1909, p. 29) and H. J. B. Wollaston (1911, p. 218). For notes on the eggs of the Mediterranean mackerel we are indebted to Holt (1899, p. 103) and L. Fage (1910, p. 33); similar information in regard to the American mackerel has been furnished by A. Agassiz and Whitman (1885, pl. XVII, 1) as also by Brice (1897, p. 209—213) and especially by J, P. Moore (1899, p. 1—22).

My measurements of mackerel eggs from the North Sea give a diameter of these of from 1.0 to 1.38 mm. The average size for end May in the southern North Sea amounted to 1.276 mm gradually decreasing to 1.101 by mid-July; north-west of the Dogger, I found, at the end of June, an average of 1.139, and on the 21/6, west of the Viking Bank in the northern North Sea, the somewhat high average of 1.210 mm. The measurement results given by other writers show a satisfactory agreement with these figures. Tesch gives, as the mean of 73 eggs, taken 2—6 July 1908 off the coast of Holland, 1.157 mm and Wollaston for 200 taken 7 June 1909 off Helder, 1.186 mm.

The following is a survey of my own more recent measurements (earlier figures were published by me l. c. 1900, Appendix).

The oil globule of the mackerel's egg is 0.28 to 0.35 mm in diameter and its comparatively large size affords, in the North Sea, the best means of distinguishing the eggs from those of the gurnard, which have a similar diameter for the egg itself but a somewhat smaller oil globule. Gurnard eggs, however, are, at an advanced stage of development, also distinguishable by the pigment spread about the yolk, which pigment is lacking in the ova of Scomber; furthermore, gurnard eggs will always be found to average a somewhat larger size than synchronical mackerel eggs.

Among other eggs found in the northeuropean waters and resembling those of the mackerel, those of *Caranx trachurus* deserve mention, having an oil globule of similar size, and similar embryonal pigment; they are, however, most readily

[1] cf. the earlier Reports in Rapports et Procès Verbaux du Conseil International pour l'Exploration de la Mer. Vol. XIV (1912) and Vol. XVIII (1913).

[2] The dates and figures behind the author names refer to the list of literature at the end of this paper.

Measurements of mackerel eggs, in micrometer intervals of 0.0314 mm.

Date and Locality	31	32	33	34	35	36	37	38	39	40	41	42	43	44	Total	Average = mm
31. 5. 00 40 ml. NW of Helgoland							1.5	3	19	24	26.5	19	5	2	100	40.580 = 1.276 mm
15. 6. 00 40 ml. NW of Helgoland					1	9	27.5	35	17.5	5	4.5	0.5			100	37.945 = 1.193 »
2. 7. 00 20 ml. NW of Helgoland			0.5	5	17.5	30.5	36	10.5							100	36.280 = 1.141 »
18. 7. 00 20 ml. NW of Helgoland		2	5	23	37	26.5	6	0.5							100	35.010 = 1.101 »
30. 6. 05 55° 57′ N 1° 20′ E 77 m depth NW of the Dogger				8.5	38	84.5	58.5	17.5	1.5	1	0.5				210	36.236 = 1.139 »
21. 6. 05 60° 25,5′ N 1° 45′ E 111 m depth W of Viking Bank						3	13	37.5	30	12.5	3	1			100	38.490 = 1.210 »
American mackerel, artificially fertilized, measured after preservation: 20. 3. 12.					7	19	20	33	20	1					100	37.43 = 1.177 »

distinguished by the somewhat inferior diameter of the egg and the segmentation of the yolk.

The eggs of the American mackerel are, as far as can be judged from the measurements available, almost entirely equal in size to those of the European form. AGASSIZ and WHITMAN give as the size of the mackerel-like egg they figure, 1.15 mm and that of the oil globule as 0.28 mm. J. P. MOORE also gives some information as to the size of mackerel eggs, and reckons the average size of a number of eggs of different origin (l. c. 1899, p. 6) as 1.25 mm; the limit of variation for a single individual he gives as 1.16 to 1.29 mm: two lots of eggs, measured in Woods Hole, showed an average of 1.15 mm and average size of the oil globule 0.28 mm. In a measurement carried out in my laboratory using preserved American mackerel eggs sent me by Dr. HUGH M. SMITH, of Washington (see table above) the size of the eggs varied between 1.10 and 1.26, the size of the oil globule between 0.27 and 0.34 mm; average diameter of the egg, after 100 double measurements, amounted to 1.177 mm. Unfortunately, with this material as with the other American measurements, there is no record of the season of year at which the eggs were found.

With regard to the size of mackerel eggs in the Mediterranean, we have unfortunately but little definite information; we may, however, with a probability approaching certainty assert that they are smaller than the eggs of the Atlantic mackerel, a point, which in conjunction with other features seems to suggest that a racial difference exists between the two forms. HOLT's measurements, which very probably concern a true mackerel egg, give the diameter of the ovum as 0.86 to 1.04, and that of the, mostly coloured, oil globule as 0.20 to 0.22 mm (1899, p. 103). L. FAGE, unfortunately, gives no measurements of his own for mackerel eggs, but confirms the correctness of HOLT's determination of these eggs (1910, p. 34). The identification, however, by artificial fertilisation of eggs of the

Mediterranean mackerel, and their certain distinction from those of *Scomber colias*, still remains to be effected.

In the course of development, black pigment in dendritic forms appears in the egg at an early stage, and this in the covering of the oil globule as well as in the body of the embryo, in which latter it generally appears arranged in two longitudinal rows. When the embryo embraces about $^2/_3$ of the periphery of the yolk, a second pigment appears, of particularly characteristic shade and distribution; at first dull greenish yellow, later mossgreen, showing yellow to yellowish brown in reflected light. This pigment is as a rule only seen in two small spots on either side between the eye and the otocyst, with a third in the covering of the oil globule. The hatching larva also, which is from 3.3 to 3.9 mm long, displays this pigment in the same way, only occasionally increased by a small group on the forehead. The American and Mediterranean mackerel seem, in contrast to the North European form, to have this mossgreen pigment moreover medially in the post-anal part of the body, set in two small groupings, facing each other on the dorsal and ventral side of the chorda.

The duration of embryonal development varies according to locality, and is mainly dependent upon temperature; it seems, however, apart from this, to be longer in the case of the North European mackerel than with the American. J. T. Cunningham found that the period of incubation at 20° C. amounted to 5—6 days, — on the spawning grounds at a distance of 14—50 miles from the south coast of England he noted a temperature of 12° C. — J. P. Moore, on the other hand, working on American mackerel, found that the hatching of the larvæ at an average temperature of 13° C. took place after 120 hours, i. e. 5 days; black pigment began to appear after 52 hours, and the yellow behind the eyes after 88 hours.

During development, the egg becomes heavier, and sinks, as a rule, to deeper water layers.

With regard to the behaviour of the mackerel during spawning, but little is known. Holt has, as he informed me in writing, arrived at the conviction that the mackerel in full spawning do not rise to the surface with the others of their species; for he has never found mackerel with the spawn flowing in anything like such great numbers as the nearly ripe fish just before; fish just spent also, are, in his opinion, not taken in such great numbers. It is altogether remarkable that the larger fish seem to disappear about the end of the spring season, although these fish would not be in great demand from the economical point of view.

A similar behaviour on the part of the American mackerel would seem to be indicated by an observation of J. W. Collins, to the effect that in the Bay of St. Lawrence, in the spawning season proper, i. e. first half of July, a pause generally occurs in the mackerel fishery, as the mackerel then sink to the bottom to spawn. So at least the fishermen say; but in any case they do move down into deeper water layers, where they are not to be taken by hook.

Other reports also, as quoted by Br. Goode in his »History of the mackerel fishery« indicate the locality of spawning as in »comparatively deep« water, and Capt. Atwood, who furnishes other seemingly reliable information, gives the depth as from 5—15 fathoms.

Several writers have attempted to show that the spawning depends upon certain conditions of temperature and salinity; up to the present, however, this cannot be regarded as proved. The mere fact that spawning takes place in June in the Irish waters, in the Skagerak and Kattegat as well as in the south-eastern North Sea at the same time, is evidence enough that it is not restricted to any fixed degree of temperature. Generally speaking, however, we can probably say that the mackerel — both on the European and on the American side — seek water of much lower temperature and less salinity than that in which they lived until the spawning set in. With regard to salinity, a certain minimum is naturally indispensable to the occurrence of mackerel eggs. The Swedish writer D. Nilsson, who has studied spawning conditions in the Skagerak, gives the lower limit as 26 ‰. He found that the eggs of the mackerel were far less numerous in the upper water layers of these seas, where the Baltic water makes itself apparent, than in the salter strata beneath, and that towards the entrance to the Sound they were of far less frequent occurrence, or found to be abnormal and decaying.

As regards the time at which mackerel eggs have been observed in the various seas, and which must thus be taken as the spawning season of the mackerel, a wide conformity of opinion exists. Cunningham, who made his observations from Plymouth, states that spawning there lasts from the end of May to the last part of July; and adds: »the period seems to be distinctly limited between these times«, and the later statements of Allen (1917) entirely confirm this. Exactly the same times have been noted also on the shores of the North Sea, e. g. off Helgoland; and the point is the more to be emphasised from the fact that most other fish — bottom fish that is — which spawn both in the English Channel and in the North Sea, have their spawning time in the former water from one to two months earlier than in the latter. This uniformity in the spawning time of mackerel in areas lying far apart seems most certainly to point a common or uniform origin of the fish themselves, to the derivation of all or nearly all spawning fish from the Atlantic Ocean, say from the western and north-western continental shelf of northern Europe.

Certainly, the planktonic eggs of the mackerel have also been observed, by Holt, in the Irish waters at a somewhat earlier period. The eggs he figures (1893, pl. 1, fig. 1—7) were taken as early as the end of April (the 30th) and beginning of May. Nothing is stated, however, as to whether the eggs were then met with in numbers or not; fully ripe fish, and these moreover, only males, were not found until the 12th of May (Valencia) (Holt 1892, p. 392), and W. Sp. Green (1894) also gives the spawning season for the south-west coast of Ireland as May and June.

In Scandinavian waters, also, the mackerel seem, by all appearances, to spawn at the same time as in the south-eastern North Sea. True, G. Sars states that the spawning season is limited to the first two weeks of July; Ekström, however, referring to Bohuslän, notes also June as the spawning time here; D. Nilsson has recently given the time as end June to early August; and on the cruises of the »Michael Sars« in Norwegian waters, according to the hitherto unpublished observations of Dr. D. Damas, placed at my disposal by Dr. Hjort, great quantities of planktonic eggs were constantly taken from 18. June to mid July in 1904, i. e. apparently throughout the entire duration of the cruise in question. Moreover, numerous

eggs must evidently have been present even before the 18. June, as the first hauls commenced at once with more than 1000 eggs per horizontal haul (see table p. 10). What I consider of particular importance in this connection however, is the result obtained by A. Otterström (1906, p. 75—76) who found in the Kattegat, off Anholt and west of Kullen, considerable numbers of floating mackerel eggs in July, and, in contrast to D. Nilsson, also as early as the beginning of June. As no eggs of this species were then found in the Belt, it is thus evident that on the extreme verge of the spawning area, eggs were present already in early June, exactly as in the south-eastern North Sea.

A very remarkable point is the fact that the spawning time of the American mackerel coincides very completely with that of the North-European form, and that the various parts of the North-American coast do not show any great difference in the periods of spawning. Brown Goode notes that in the southern New England states, spawning takes place in May, in Massachusetts Bay May and June, and in the Bay of St. Lawrence early June, on the north-east coast of Newfoundland end June (according to Hind). J. W. Collins remarks in this connection that according to his experience, the mackerel in the Gulf of St. Lawrence do not spawn until the first half of July. Captain Atwood saw mackerel with running spawn in Massachusetts Bay at the beginning of June, and believed that the spawning would in a few days (by the 10/6) be already at an end. Presumably none of these indications as to spawning time is altogether wrong; all, however, appear to give too short a period, and it is not unlikely that spawning is in progress along the entire coast line at approximately the same time, as is the case on the European side of the Atlantic; that it lasts from May — and even from the middle or the beginning of May — to mid July, and that the difference between commencement of the spawning in south and north does not amount to more than half a month, or a whole month at the outside. Only once have I found an observation which does not agree with this; in the U. S. Fish Commission Report for 1895, p. 80. Hardin states that he found in the New York market some mackerel with sexual organs entirely spent, the fish having been taken on the 7th of April abt. 65 miles S. E. of Cape Henry. The value of such observations as these, however, may be regarded as doubtful. It is only by systematic investigations as to the quantitative distribution of the planktonic eggs that we can attain the requisite clarity in regard to the periods and extent of the spawning.

Finally, it should be noted that the spawning season of the Mediterranean mackerel is altogether different: it occurs almost exactly two months earlier than that of the Atlantic form, i. e. chiefly in the months of March and April.

Investigations of the quantitative distribution of mackerel eggs have not, up to the present, been often made; in some parts of the North Sea, however, they have served to augment in an essential degree our knowledge of the spawning grounds of the mackerel. This applies especially to the previously mentioned investigations of Tesch, Wollaston, Damas and myself.

The German investigations were made chiefly off Helgoland, and in the region of the German Bight and adjacent waters; and I have given a full report of these (1907, p. 248—251). The area investigated extends north as far as the Mud

Bank, west as far as the Dogger Bank, and at several points of the area, considerable quantities of mackerel eggs were noticed, most in July — maximum 153 eggs per sq. metre surface, 25 miles N. W. of Helgoland on the 19. July 1901 — and in June: 126 eggs per sq. m. 14 miles W. N. W. of Helgoland on the 9. 6. 04. At most points however, fewer eggs were found, sometimes about sixty and generally from 20 to 40 per sq. m. Some of the eggs were found in the immediate vicinity of the coast, but those within the 20 m depth line were not very numerous.

To these data must be added some hitherto unpublished observations, made from 19.—30. June 1905, on a »Poseidon« cruise in the north and north-western parts of the North Sea. Considerable hauls were made at the following localities: 22. 6. 05 north of the Viking Bank, at 182 metres depth, 135 mackerel eggs per sq. metre; on the 30. 6. 05 north-west of the Dogger, 77 metres, 102 eggs per sq. m. and 54 larvæ, on the 23. 6. 05 northernmost North Sea (»Tampen«) at 190 m, 80 eggs per sq. m. and 2 larvæ, on the 21. 6. 05 west of the Viking Bank, 111 m, 74 eggs per sq. m,, and 20. 6. 05 northern North Sea 58° 36′ N, 2° 11′ E 30 eggs per sq. m.

It is remarkable that the Dutch investigations, which were specially directed towards the study of planktonic eggs and larvæ, and were carried out in May and June, off the coast of Holland and in the south-western North Sea, never succeeded in discovering any great quantity of mackerel eggs at all. For many years, only a few isolated mackerel eggs were found here, though the Dutch investigator, J. J. Tesch (l. c. 1909, p. 30) in another part of the North Sea — on the north edge of the Great Fisher Bank, 58° N, 3° 11′ E — found up to 189 mackerel eggs per sq. m. on the 2. July 1908.

The view expressed by Tesch and myself, however, on the basis of these finds, that the spawning area of the mackerel in the south-eastern North Sea does not appear to have any continuation to the westward (Ehrenb. 1907, p. 250) cannot be maintained in the face of subsequent English investigations. Though the mackerel eggs in the south-western North Sea may be lacking, or but sparingly found, in many years, this is evidently not always the case, as H. J. B. Wollaston (l. c. 1911, p. 211 ff. and 218) found very considerable quantities in the Flemish Bight in June 1909. A chart given by this writer shows that while in the Deep Channel as well as west, north and south of the same, off the English coast and at the entrance to the English Channel, at about a dozen different stations, no mackerel eggs, or very few — up to 10 per sq. m. — were observed, the number, however, increased on approaching the coast of Holland, five stations here giving up to 30 eggs per sq. m., and on two occasions, not far from the Hoek of Holland and near Haaks Lightship, 37 and 214 eggs per sq. m. respectively were found. It is thus evident that in many years, considerable quantities of mackerel eggs are present in these waters, though in other years they may be lacking; and this is entirely in agreement with the fluctuating yield of the mackerel fishery on the coast of Holland and in the Sealand Streams, as noted in the Dutch statistics.

It is remarkable that off the eastern shores of England (coasts of Kent, Suffolk and Norfolk) mackerel eggs are almost entirely lacking, or very sparsely found, while it is known that some of the fishing stations situated here, especially Yarmouth and Lowestoft, carry on a not inconsiderable mackerel fishery, and that, moreover,

in the very months of May and June, during the mackerel spawning season, as stated in my first report (1914, p. 47).

We may, however, presume from the foregoing, that further continued search for the eggs might perhaps be no less successful here than off the coast of Holland, where the eggs, though lacking in some years, were later (1909) found in considerable quantities.

Observations of planktonic mackerel eggs in the Scandinavian waters are very numerous. As already mentioned, Otterström found eggs in the Kattegat (1906, p. 75—76) and A. W. Malm on the Swedish coast of the Skagerak; there are also the numerous unpublished finds of mackerel eggs from the cruises of the »Michael Sars« in 1904, placed at my disposal by Dr. Hjort and noted in the survey here given. These observations were apparently made with a vertical net, not quite equal in size to the Hensen type, but very similar. The anterior diameter of the Norwegian net was 1 metre, as against 70 cm in the Hensen net, and the inflow aperture of the former then about twice as large as that of the latter implement. A rough estimate then — necessarily very inaccurate, from lack of knowledge of the Norwegian net's construction — shows that the figures for the Norwegian hauls would have to be multiplied by about $1^1/_2$ in order to give the amount per surface unit of one square metre as with the others. Proceeding on these lines, we find that the number of mackerel eggs on the coasts of Norway must be essentially greater than in the previously mentioned areas of the North Sea; it is, however, to be regretted that only in comparatively few places the vertical net was used, the hauls being made for the most part exclusively with horizontal nets. It seems nevertheless, that in the very places where the vertical net was used, to wit, in the Skagerak area, mackerel eggs were particularly abundant, while in the northern and middle parts of the North Sea, where only horizontal nets were used, smaller quantities were apparently found. In the Skagerak, between 8° and 11° E, and 57°—59° N, were observed the greatest quantities of mackerel eggs hitherto noted, viz. sometimes over 500, and max. 669 per sq. m. The localities in question are very close to the south coast of Norway, the districts of Bratsberg, Jarlsberg and Larvik, where, as previously mentioned (1914, p. 27) a considerable coastal mackerel fishery is also carried on. In other parts of the Skagerak also, and in the Kattegat, great quantities of mackerel eggs were found. Towards the west coast of Jutland however, the quantities appear to decrease. These are also numerous points in the northern North Sea, where mackerel eggs were found in the Norwegian hauls, even north of Tampen, over very deep water, a few isolated eggs were — as in the German observations — also found.

These results are supplemented by the Swedish investigations from the years 1911 and 1912, fully described by D. Nilsson (1914, p. 43 ff. app. 2). These hauls were likewise, save for some insignificant exceptions, made with implements fishing horizontally, only 3 with vertical nets, and these not, apparently in the most important parts of the spawning grounds. No comparison with other figures reduced to the unit of sq. m. surface is therefore possible; more especially as information as to the size of the vertical net is also wanting. Anyhow, several net hauls made from 1—20 metres depth and sometimes also from 30—40, gave great quantities of

Eggs and young forms of mackerel from hauls made by the Norwegian research steamer »Michael Sars« in 1904

Determined by Dr. DAMAS, communicated by Dr. O. SUND.
H = Horizontal net (Dm. 1 m), V = Vertical net (Dm. 1 m).

J.-No.	Date	Position	Implement	Depth in m	No. of eggs	Larvæ	Remarks
209	18. June	58° 47′ N 5° 24′ E	H 5 Min.	0	558		
210	—	58° 23′ N 5° 53′ E	V	20—0	102		
—	—	— —	H 5 —	0	155		
211	—	— —	H 5 —	0	1326		
212	19. June	57° 41′ N 5° 35′ E	V	20—0	41	—	all stages
221	21. June	58° 25½′ N 9° 25′ E	H 5 —	0	8		
222	—	58° 50½′ N 9° 38′ E	V	50—20	65		
—	—	— —	V	20—0	446		
—	—	— —	H 5 —	0	1557		
223	—	58° 53′ N 9° 52′ E	V	50—25	2		
—	—	— —	V	20—0	391		
—	—	— —	H 5 —	0	in masses		
224	—	58° 58′ N 10° 8′ E	V	20—0	great quantities		
—	—	— —	H 5 —	0	some hundreds		
225	22. June	58° 43′ N 10° 27′ E	V	50—20	11		
—	—	— —	V	20—0	great quantities		
—	—	— —	H 5 —	0	enormousquantities	—	all stages
226	—	58° 29′ N 10° 49′ E	H 10 —	0	—		
227	24. June	57° 29′ N 10° 42′ E	H 5 —	0	18		
228	—	57° 47′ N 10° 51′ E (Skagen)	V	40—20	20		
—	—	— —	V	20—0	48		
—	—	— —	H 5 —	0	60	—	all stages
229	—	57° 55′ N 10° 27′ E	H 5 —	0	frequent	—	all stages
230	—	58° 11′ N 10° 26′ E	H 5 —	0	in masses		
231	—	58° 28′ N 10° 24′ E	V	50—20	1		
—	—	— —	V	20—0	142		
—	—	— —	H 5 —	0	enormous masses	—	all stages
232	—	58° 44′ N 10° 27′ E	H 5 —	0	several thousand		
233	25. June	58° 52′ N 10° 10′ E	H 5 —	0	a few hundred		
234	27. June	— —	H 10 —	0	81		
—	—	— —	V	20—0	159		
235	—	58° 16′ N 9° 12′ E	V	20—0	abt. 100		
—	—	— —	H 5 —	0	several thousand		
236	—	58° 2′ N 9° 11′ E	V	50—20	1		
—	—	— —	V	20—0	77		
—	—	— —	H 5 —	0	abt. 1000		
237	—	57° 48′ N 9° 21′ E	V	50—20	2		
—	—	— —	V	20—0	26		
—	—	— —	H 5 —	0	several thousand		
238	—	57° 32′ N 9° 21′ E	V	18—0	20		
—	—	— —	H 5 —	0	6		
239	—	57° 18′ N 9° 15′ E	V	14—0	3		
—	—	— —	H 5 —	0	50		
240	—	57° 38′ N 8° 57′ E	V	50—20	1		
—	—	— —	V	20—0	15		

J.-No.	Date	Position	Implement	Depth in m	No. of eggs	Larvæ	Remarks
240	27. June	57° 38′ N 8° 57′ E	H 5 Min.	0	428		
242	28. June	58° 3′ N 8° 9′ E	H 5 —	0	thousands	—	over 20.000 eggs of Scomber, Motella and Labrus.
251	29. June	57° 37′ N 8° 1′ E	V	20—0	61	—	all stages
—	—	— —	H 5 —	0	in masses		
252	—	57° 20′ N 8° 2′ E	V	50 – 20	1		
—	—	— —	V	20—0	11		
—	—	— —	H 5 —	0	in masses		
253	—	56° 54′ N 8° 10′ E	V	20—0	3		
—	—	— —	H 5 —	0	131		
257	—	56° 3′ N 6° 5′ E	H 5 —	0	224		
258	30. June	56° 2′ N 5° 28′ E	H 5 —	0	in masses		
259	—	56° 1′ N 4° 49′ E	H 5 —	0	89		
260	—	55° 58′ N 3° 49′ E	V	50—30	1		
—	—	— —	V	20—0	15		
—	—	— —	H 5 —	0	92		
261	1. July	55° 52′ N 3° 11′ E	V	20—5	5		
262	—	55° 44′ N 2° 35′ E	H 5 —	0	125		
263	—	55° 44′ N 1° 49′ E	H 5 —	0	117		
264	—	55° 55′ N 1° 17′ E	H 5 —	0	107		
265	—	56° 7′ N 0° 42′ E	H 5 —	0	185		
266	2. July	56° 19′ N 0° 5′ E	H 5 —	0	69		
275	6. July	57° 9′ N 1° 30′ E	H 5 —	0	92		
276	—	57° 8′ N 2° 11′ E	H 5 —	0	27		
277	—	57° 6′ N 2° 58′ E	H 5 —	0	228		
278	7. July	57° 4′ N 4° 14′ E	H 5 —	0	62		
279	—	57° 37′ N 3° 37′ E	H 5 —	0	abt. 1000		
280	—	58° 37′ N 2° 56′ E	H 5 —	0	500		
281	—	58° 34′ N 3° 6′ E	H 5 —	0	70		
282	8. July	58° 17′ N 3° 49′ E	H 5 —	0	200		
284	—	58° 15′ N 5° 24′ E	H 5 —	0	47		
287	14. July	60° 33′ N 4° 13′ E	H 5 —	0	36	—	all with embryo
288	—	60° 21′ N 3° 39′ E	H 5 —	0	300		
289	—	60° 9′ N 3° 9′ E	H 5 —	0	600		
290	—	59° 53′ N 2° 28′ E	H 5 —	0	200		
291	—	59° 38′ N 1° 48′ E	H 5 —	0	100		

eggs, numbered by the thousand, besides hundreds of young larvæ. Quite unusually great was the number of eggs found during the period 1.—6. July 1911 in the open waters of the Väderöfjord, on the landward side of the islands of that name, where in the course of ten minutes, about 5000 eggs were found at the surface, and also at 5 m depth, off Hallö too, as well as from Paternoster and thence diagonally across to the Skaw, numerous eggs were found.

Considerably fewer were the eggs found in the Kattegat, though here also, especially in the northern part, they were by no means wanting. On nearing land, however, the eggs very rapidly decreased in number, and in the Sound itself they were no longer found.

It will thus be seen that mackerel eggs are to be found in more or less considerable quantities in practically all parts of the North Sea and the Skagerak.

The eastern part of the North Sea, however, with the Skagerak, seems essentially richer in these eggs than the western part. In the immediate neighbourhood of the British coast, the eggs seem to be very sparsely found, and perhaps more so in the north than in the south.

II. Larvæ, postlarvæ and young of the mackerel.

The appearance of the mackerel larvæ is described by me in Nord. Plankton (p. 33 ff.) on the basis of my own observations and also those of Cunningham and Holt. Meanwhile, E. J. Allen (1917, p. 227) has also given some illustrations of young mackerel larvæ, of 6, 9, 11.5 and 16 mm length, in the Plymouth Journal; these again are further supplemented by a number of figures published by me in the Wissenschaftl. Meeresuntersuchungen (Abt. Helgoland Bd. XV, 1921) and which are reproduced herewith, as showing not only intermediate stages, but also some larger ones not hitherto known, up to a size of 43 mm.

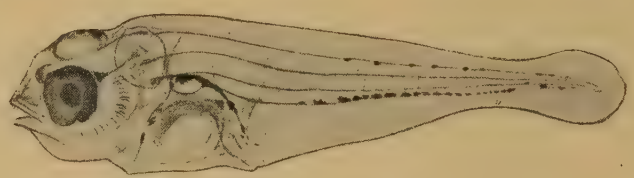

Fig. 1. Larva, 5 mm long, taken 7. July 1903, 30 miles NW of Helgoland.

Fig. 2. Larva, 7,2 mm long, taken 7. July 1903, 30 miles NW of Helgoland.

The youngest form here shown (Fig. 1) which is abt. 5 mm long, and was taken not far from Helgoland on the 7. 7. 03, shows as yet no rays in the unpaired fins, and exhibits the characteristic distribution of pigment along the sides of the body (in profile) as well as in the peritoneum and air bladder.

Fig. 2 shows a larva of 7.2 mm taken at the same place, with pigment distributed in the same way, but more intensively developed, especially on the ventral side of the body. Beneath the upturned urostyle, the indication of the definitive caudal fin is discernible, in process of replacing the embryonal fin; the region of

the radial elements for the support of the 2. dorsal and especially the anal fin, is also now visible; it is already easily seen that the insertion of the latter is situated rather far behind the anus.

Fig. 3 shows a larva of 8.6 mm taken by the Danish research steamer »Thor« in the English Channel, 27. 6. 05. It shows, apart from the further development of the caudal fin, no essential progress beyond the stage shown in Fig. 2; the pigment is fainter rather than more pronounced, but is more clearly defined at the base of

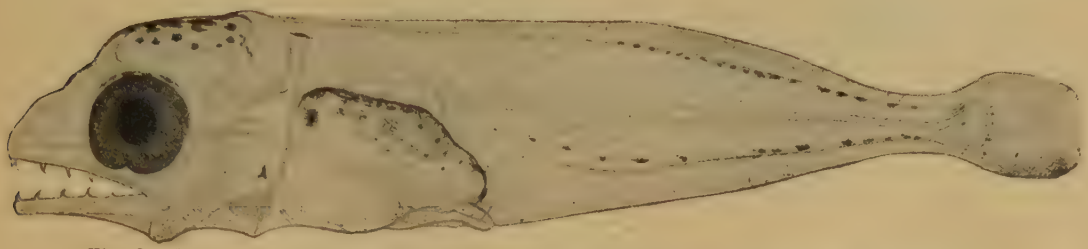

Fig. 3. Larva, 8,6 mm long, taken 27. June 1905, English Channel. Johs. Schmidt lgt.

Fig. 4. Larva, 13,2 mm long, taken 2. August 1904, Risör. K. Dahl lgt.

the caudal fin; characteristic are the teeth, inserted at wide intervals, which are also visible in the younger stages. In the next following stages, the development of rays in the unpaired fins makes marked progress, being far advanced in the larva of 11 mm.

In Fig. 4, a larva of 13 mm represented by a specimen from Risör, on the coast of Norway (preserved in alcohol), the development of the unpaired fins has made great progress; the caudal is now at its final place and the posterior margin somewhat concave; in the anal and dorsal fins, the anterior rays stand noticeably closer together than the posterior, the latter representing the pre-formation of the 5 finlets which are later separated off. Particularly striking is the wide interval between the insertion of the anal fin and the anus itself, though the latter, in course of development, has already moved considerably farther back and is near the middle of the body. The development of the first dorsal fin is faintly indicated by a slight rise in the forepart of the embryonic fin; the germs of the ventral fins, however, are more distinct.

Fig. 5 is a larva of 16 mm long, taken end July by the »Thor« in the Skagerak. The principal advance in this stage is the formation of the fin rays in the first dorsal, and a forking of the caudal extending for about half its length. In the 2. dorsal and the anal, the finlets are already discernible; the anal fin is still far from the anus, ventral fins essentially longer; the teeth have noticeably increased

in number and are therefore closer set, the upper jaw projects with a pair of hooked teeth beyond the lower; the distribution of pigment remains the same. The vertebræ, already discernible at earlier stages, can now be counted exactly; they number 31, with 13 ventral. The supporting radial element of the first ray in the anal fin joins the 14th vertebra, which is the first caudal.

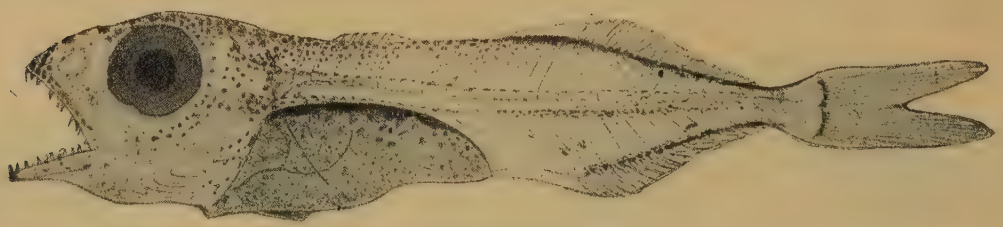

Fig. 5. Young fish, 16 mm long, taken 27. July 1906, Skagerak. Johs. Schmidt lgt.

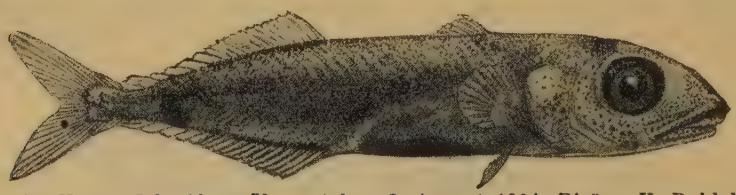

Fig. 6. Young fish, 19 mm long, taken 2. August 1904, Risör. K. Dahl lgt.

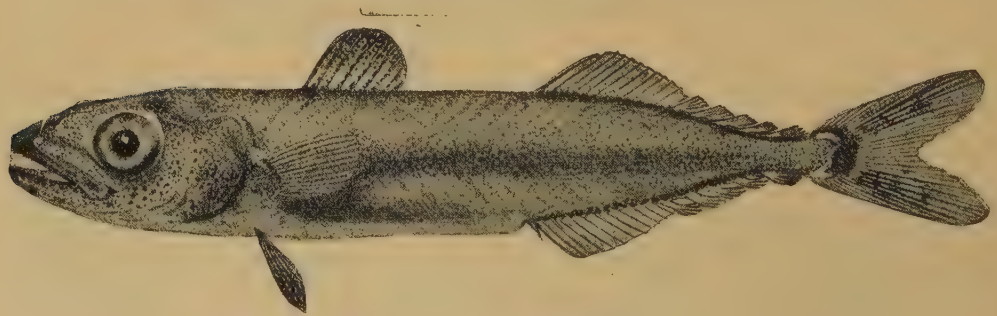

Fig. 7. Young fish, 43 mm long, taken 19. July 1905, Risör. K. Dahl lgt.

Fig. 6 shows a small fish of 19 mm, taken 2. 8. 04 at Risör. This specimen shows further marked progress in regard to development in the definite shape. All the fins have now approximately attained their definitive form, though the finlets are still very close together; there is no connecting embryonic fin; the interval between the anus and the anal fin has noticeably decreased. The ventral surfaces are beginning to take on a silvery sheen.

Fig. 7, showing a young fish of 43 mm taken 19. July 1905 at Risör, may serve as an illustration of the fully developed fish, albeit with the finlets still very close together, and no scales yet present, so that it lacks the glittering colours of the

adult; otherwise, the bodily proportions answer in essentials to those of the fully developed fish. A certain distance still exists between the anus and the insertion of the anal fin and is kept on.

The number of larvæ, which were found simultaneously with the eggs in the German, Dutch, English, Danish, Swedish and Norwegian hauls, is, as far as can be judged from the data, not always in the same proportion to the quantity of eggs. Generally, only isolated specimens are taken. They were particularly numerous in the German, Danish, English and Swedish hauls, many were still youngish, often still retaining the yolk sac, and some without eye pigment.

The German cruises yielded the greatest quantities in the southern and middle parts of the North Sea, on the 16. 6. 04, at 54° 16′ N and 6° 30′ E, 37 m depth (59 specimens), at 54° 6′ N, 6° 47′ E, 34 m depth (91 specimens) and on the 30. 6. 05 at 55° 57′ N, 1° 20′ E, 77 m depth (92 specimens). In July, also somewhat older larvæ were repeatedly observed, up to a length of 14 and 16 mm. No larvæ beyond this size however have been taken by the German experiments.

In the Swedish hauls noted by D. Nilsson, the mackerel larvæ appear in extremely varying quantities, often lacking, often in small numbers, but occasionally in very great quantities up to 500 specimens in one haul with the ordinary townet. The richest hauls of larvæ were made in early July 1911 in the Skagerak off the northern part of the west coast of Sweden; the specimens taken were as a rule not more than 10 mm long, only a very few 13 to 14 mm; they were taken for the most part at the surface, or at 5 to 10 metres depth, more rarely also at 30 to 40 metres.

The records of the Norwegian hauls show far fewer larvæ, and in the Dutch, they are even more rare. In the southern English waters, at Plymouth and off the coast of Ireland, where the embryonal development of the mackerel has been studied, it was mostly only early larval stages that were observed, specimens over 16 mm never being taken at all. Nevertheless, it cannot be asserted that such forms do not also occur there, where the eggs are found. Evidently it is only that they have not been fished for intensively enough. It is remarkable, however, that the same investigator (Holt) who observed them in the eastern part of the North Sea in July 1891, in sizes from 7 to 9.5 mm and soon after in sizes from 14 to 18.5 mm (1892, p. 396, and 1899, p. 33) should state that they have not been found in the vicinity of the Irish coast. Holt himself informed me that the Irish investigations of recent years, since the introduction of closer fishing implements, had been working farther from the coast, at depths of 100 to 1000 fathoms, and that in these areas, at any rate, no mackerel larvæ had been found, though there is still the possibility that they may be found in the immediate neighbourhood of the shore.

Later captures of mackerel larvæ at Plymouth have been described by E. J. Allen (1917, p. 226), M. V. Lebour (1918, p. 439) and R. S. Clark (1920, p. 223). The following hauls of larvæ were noted, the average sizes being, as will be seen, much the same whether taken at the beginning or towards the end of the spawning period.

The hauls comprised:

25. V — 3. VI	1914,	117	larvæ of	5	—11.5 mm,	average	length:	6.5 mm	(Allen)
10. VI —29. VI	—	5—8	—	- 5	—12.5 mm	—	—	8.8 mm	(Allen)
15. VII—22. VII	—	3	—	- 8.5—16	mm				(Allen)
27. VII—20. VIII	1917,	20	—	- 3	—8.5 mm	—	—	5—6 mm	(Lebour)
7. IX	—	3	—	- 7	—16 mm				(Lebour)
7. VII—13. VIII	1919,	178	—	- 5	—13.5 mm	—	—	abt. 8 mm	(Clark)
of which in Aug.		42	—	- 5	—13.5 mm	—	—	abt. 8 mm	(Clark).

From this we may take it that, as ALLEN also states, fresh shoals of fish are constantly arriving in the neighbourhood of Plymouth to spawn; on the other hand, however, it is evident that the growing larvæ must either move away or else were not captured in proportion to the actual length present, and the larger sizes not at all.

An early migration from the actual spawning ground has repeatedly been assumed and by several writers; it is, however, highly improbable, since larger larvæ have been taken, where suitable implements and accompanying measures were used, as will be seen from the following.

In the Danish investigations in the North Sea, made by JOHS. SCHMIDT with the »Thor« we find that as early as the years 1905 and 1906, essentially more intensive fishing implements were used for planktonic organisms than formerly, to wit the young-fish trawl, which has since been generally adopted. True, even this net did not avail to capture the larger larvæ in very great numbers; they were, however, obtainable by this means, and SCHMIDT's hauls, made from mid-June to mid-August, and kindly placed at my disposal for investigation, contained, as will be seen from the following table, for the first time some larger young stages up to 21.5 mm. Altogether, we have here 87 net hauls, yielding 1768 larvæ among which, however, sizes over 15 mm were only about five times represented. That even the intensively working young-fish trawl itself does not capture mackerel larvæ in proportion to the sizes present is also proved by this, albeit an improvement is noticeable here in comparison with the smaller implements exclusively used in former days. It is worthy of note that the average sizes of the larvæ in these Danish hauls, remain the same throughout the spawning period, as in the case of the English hauls, and evidently from similar causes. This will be seen from the following table. In the course of the Danish cruises of 1905—1906, the following hauls were made at the times noted:

18. VI —30. VI	1905 ...	290	Mackerel larvæ,	average	size	7.2 mm
1. VII —22. VII	1905 ...	295	—	—	-	7.0 mm
15. VII —29. VII	1906 ...	714	—	—	-	6.9 mm
1. VIII—18. VIII	1906 ...	115	—	—	-	7.5 mm.

Joh. Schmidt's hauls of mackerel larvæ from the Danish s/s »Thor«.

J.-No.	Date	Locality	Depth in m	Implement and length of line	No. of larvæ	Size of larvæ in mm
	1905					
84	18. June	51° 24′ N 8° 18′ W South coast of Ireland	95	Ytr. 65 mw.	31	3.5 (with yolk sac) 11
85	19. June	50° 19′ N 8° 30′ W S of Ireland	120	— 25 —	1	8.5
94	27. June	50° 02′ N 6° 20′ W Scilly Isles	86	— 25 —	57	6—11
—	—	— —	86	— 65 —	3	6 and 6.5
95	—	49° 56′ N 5° 00′ W S of Falmouth	74	— 25 —	7	6.5—12
96	—	50° 15′ N 4° 19′ W off the Eddystone	50	— 25 —	11	7—12.5
—	—	— —	50	— 65 —	66	7—12.5
97	29. June	50° 17′ N 3° 14′ W E of Brixham	60	— 75 —	1	9
99	30. June	50° 43′ N 0° 43′ E off Hastings	41	— 65 —	114	5.5—11
100	—	51° 26′ N 2° 02′ E SW North Sea	45	— 25 —	6	6.5—9
—	—	— —	45	— 65 —	8	6.5—9
101	1. July	52° 21′ N 3° 21′ E —	26	— 25 —	9	5—8
—	—	— —	26	— 65 —	1	8.5
104	2. July	54° 16′ N 6° 06′ E N of Borkumreef	24	— 25 —	43	5—8.5
—	—	— —	24	— 160 —	1	4
105	—	55° 10′ N 7° 38′ E Sylt Outer reef	24	— 25 —	37	3.5—7.5
—	—	— —	24	— 75 —	6	5.5—8
—	—	— —	24	— 125 —	2	6.5
107	11. July	55° 23′ N 7° 42′ E Horns Reef	21	— 100 —	1	15
110	—	55° 52′ N 6° 24′ E NW Horns Reef	44	— 25 —	52	5.5—10
—	—	— —	44	— 180 —	3	5.5—9.5
111	12. July	56° 12′ N 4° 08′ E mid. North Sea	67	— 65 —	35	5—9
—	—	— —	67	— 250 —	3	4.5—7
112	—	56° 33′ N 1° 47.5′ E —	89	— 25 —	91	4—6.5
—	—	— —	89	— 100 —	25	4—8
—	—	— —	89	— 300 —	2	5.5
113	13. July	56° 50′ N 0° 07′ W S Long Forties	72	— 65 —	5	5.5—8.5
116	16. July	58° 46′ N 0° 07′ W NW Fladenground	140	— 65 —	30	4—7.5
117	—	59° 08′ N 1° 12′ E S Bressay Shoal	108	— 25 —	28	5—8
—	—	— —	108	— 65 —	2	5—6
118	—	59° 30′ N 2° 38′ E S Viking Bank	116	— 25 —	4	5.5—6
—	—	— —	116	— 65 —	9	6—8
119	17. July	59° 54′ N 4° 00′ E Norweg. Channel	290	— 25 —	22	6—10
—	—	— —	290	— 65 —	1	11
—	—	— —	290	— 500 —	2	11
120	21. July	61° 14′ N 1° 19′ E NW Viking Bank	160	— 25 —	5	6—13
—	—	— —	160	— 65 —	5	6—13
—	—	— —	160	— 400 —	2	6—10.5
122	22. July	59° 48′ N 1° 23′ W SW of Sumburgh Head	85	— 25 —	89	6.5—12.5
—	—	— —	85	— 65 —	12	6.5—11.5
—	—	— —	85	— 125 —	4	6.5—7.5
	1906					
118	15. July	57° 47′ N 8° 21′ E Skagerak N Hanstholm	450	sm.Ytr. 25 —	11	7.5—11.5
119	17. July	57° 59′ N 8° 04′ E — S Christiansand	535	— — 700 —	1	6.5
127	24. July	57° 47′ N 10° 39′ E NE of Skagen	75	— 25 —	8	4—7
—	—	— —	75	— 65 —	6	5.5—10.5
—	—	— —	75	— 175 —	5	5—8

J.-No.	Date	Locality	Depth in m	Implement and length of line	No. of larvæ	Size of larvæ in mm
	1906					
128	24. July	57° 47′ N 9° 20′ E NW of Hirtshals	440	Ytr. 25 mw.	1	7.5
—	—	— —	440	— 25 —	2	6 and 7
129	25. July	58° 05′ N 8° 24′ E SE of Christiansand	345	sm. Ytr. 100 —	2	8—9
—	—	— —	345	- — 200 —	1	4
—	—	— —	345	- — 250 —	2	6.5—7.5
—	—	— —	205-285	- — 400 —	2	8.5—9.5
—	—	— —	250-520	- — 400 —	2	6.5—7.5
—	—	— —	250-520	- — 400 —	1	7
—	—	— —	520-510	- — 700 —	2	6.5—8
131	27. July	57° 36′ N 6° 38′ E S-side of Skagerak (S of Lister)	180	— 25 —	24	6—19.5
—	—	— —	180	— 65 —	4	6—21.5
132	—	57° 11′ N 6° 33′ E N-edge of Little Fisher bk.	62	— 25 —	10	6.5—9
—	—	— —	62	— 65 —	9	7—8.5
133	—	56° 41′ N 6° 23′ E Tarbot bk. (S of Little Fisher bk.)	44	— 25 —	2	4
—	—	— —	44	— 65 —	0	—
—	—	— —	44	- — 25 —	3	5.5—8.5
—	—	— —	44	- — 65 —	5	5.5—8.5
134	28. July	56° 16′ N 5° 06′ E SW-edge of N Mud bk.	63	— 25 —	382	4—9.5
—	—	— —	63	— 65 —	135	4—10
—	—	— —	63	- — 65 —	18	—
—	—	— —	63	- — 115 —	10	—
135	—	55° 56′ N 3° 43′ E N-edge of Dogger bank	71	- — 25 —	117	6.5—14.5
—	—	— —	71	- — 65 —	30	6.5—11
—	—	— —	71	- — 140 —	7	7.5—10
137	29. July	55° 15′ N 0° 58′ E NW corner of Dogger bank	75	— 25 —	6	5.5—11
138	—	55° 36′ N 2° 21′ E N-edge of Dogger bank	78	— 65 —	5	4.5—10
139	1. Aug.	54° 45′ N 0° 35′ W off Hartlepool	61	— 25 —	5	6—7
—	—	— —	61	— 65 —	1	8.5
140	—	54° 51′ N 0° 49′ E W of Dogger bank	73	— 25 —	18	4.5—10.5
—	—	— —	73	— 65 —	3	5—7
—	—	— —	73	— 140 —	2	7.5—10.5
141	—	54° 57′ N 2° 14′ E mid. Dogger bank	25	— 25 —	55	5—9
—	—	— —	25	— 70 —	6	5—6.5
142	2. Aug.	55° 03′ N 3° 27′ E SE-edge of Dogger bank	35	— 25 —	16	5.5—11.5
143	—	55° 11′ N 5° 03′ E S of Dogger tail	41	— 25 —	12	5—10.5
—	—	— —	41	— 65 —	11	6.5—12
144	3. Aug.	55° 17′ N 6° 28′ E S of Mud bk. south part	39	— 65 —	1	9.5
145	—	55° 24′ N 7° 53′ E Vyl Lightship	18	— 15 —	4	10.5—19
—	—	— —	18	— 40 —	1	11
156	18. Aug.	54° 41′ N 6° 56′ E NW of Helgoland	40	— 25 —	4	10.5—13.5
—	—	— —	40	— 75 —	1	11
158	—	53° 34′ N 3° 56′ E W of Vlieland Reef	23	— 25 —	2	12.5 a. 14

The great majority of all larvæ in these Danish hauls, viz. 65 %, were taken near the surface — with 25 metres of wire out [1] — and 31 % at slight depths with

[1] It is difficult to determine the exact depth at which the young-fish trawl actually works; the Danish records therefore, note throughout only the length of wire out during the haul. At the usual rate of speed, 2 miles an hour, maintained by the »Thor« with nets out, the depth would be approximately half the length of wire out.

65 metres of wire; further, 4 % in deeper water with 100 to 200 metres of wire and only 0.7 % at greater depths with a maximum of 700 metres of wire out. The greatest hauls of larvæ were made in the middle of the North Sea, and by far the greatest of these, yielding 382 specimens, from within 4 to 9.5 metres of the surface (25 metres of wire) on the south-western edge of the northern Mud Bank (No. 134) the next largest again in somewhat deeper water (65 metres of wire) giving 135 larvæ, and the third largest on the north edge of the Dogger Bank (J.-No. 135), close to the surface, giving 117 larvæ from 6.5 to 14.5 mm; all three hauls were made on the 28. July 1906.

These hauls of larvæ from the »Thor« seem to show that mackerel larvæ are to be found in nearly all parts of the North Sea, albeit with a certain preference for the middle North Sea, and that the larvæ, up to the size of 21.5 mm here noted have mostly not yet left their birthplace and the spawning grounds.

Instead of the supposed migration of the larvæ en masse, it seems far more likely that they spread out to all sides away from the spawning grounds. In support of this theory, we have in particular the captures of large stages, from 3, 4 and 5 to 6 cm, hitherto recorded, albeit in extremely small numbers. The paucity of finds of such young fish is, as with the post larval stages, undoubtedly due to their great rapidity and agility of movement, enabling them successfully to elude even so swiftly-moving and comparatively large a net as that of the young-fish trawl.

Knut Dahl, working in the Risör Fjord by lantern light at night, captured on the 10. July 1905 and 2. August 1904, 3 specimens of 13, 19 and 43 mm, the implements used being hand nets and a pelagic surface net. He reported these finds to the Norwegian Department of Fisheries, and the specimens were, by the courtesy of Dr. Johan Hjort, forwarded to me. I have thus been able to reproduce them here (cf. figs. 4, 6 and 7).

These three mackerel, or at any rate, the two largest, were for a long time the only known specimens of their size from northern seas. Then, on the 13. August 1913, the English fishery expert George T. Atkinson succeeded in capturing, on a very calm day in the middle of the North Sea — 56° 20′ N, 2° 23′ E — a large number of mackerel, 157 to be precise, ranging from 30 to 56 mm. Of these, 45 came into my hands. These fish were caught from a lowered boat, in hand nets; the surface salinity at the spot was 33.9 ‰, the temperature 14° C. The following sizes could be distinguished:

Length in cm	3	4	5	6	Average of 157 specimens
45 specimens	4	29	11	1	4.6

I have received similar material through the agency of the Head of the United States Fisheries Bureau Dr. Hugh M. Smith, from Woods Hole, the well-known Biological station on the coast of Massachusetts. These young fish were taken on the 17. June and 1. July 1906, and much resembled the before-mentioned Norwegian specimens in point of size:

Length in cm	3	4	5	6	average size
34 specimens	1	3	28	2	5.4 cm.

In the Mediterranean, similar young forms of the mackerel are well known, and, although these of course belong to a local variety, distinct from that of the northern waters, the observations of these young forms may nevertheless be briefly mentioned here.

The earliest larval development stages of the Mediterranean mackerel have only been observed in a few specimens of 10 to 15 mm mentioned by L. Fage. Somewhat larger stages, however, from 20 mm upwards, are regularly captured in very great numbers on the south coast of France, and that in the immediate vicinity of the shore, being taken in large sunk nets, the so called mugelières, and in a kind of shore seine (bourgin), the largest quantities being found at Nice, near the mouth of the Var. On the shores of the Mediterranean, it is a very common thing for even the smallest sizes of fish to be brought to market, and the very young mackerel are thus also liable to this fate; they are captured in quantities amounting to many kilogrammes. The period during which they were observed extended, in the year 1891, from mid-April to early August; in 1890, they were already being caught from the 22. March onwards, and mostly in sizes from 5 to 5.8 cm. As a guide to their age and rate of growth, the following observations by Gourret (1891, p. 57) will be of interest. The captures on the dates noted were as under:

17.—23. April...	— kg	of 4—8.5 cm	
10.—13. May ...	30 -	- 2—3 -	and same time in May
11.—12., 14. and 17.	— ...	31 - - 3—4 -	415 kg of 10—15 cm
23.—26.	— ...	6 - - 3—5 -	298 - - 10—20 -
29.—31.	— ...	25 - - 3—6 -	20 - - 15—25 -
1.— 3. June...	140 -	- 12—15 -	120 - - 20—25 -
20.	— some	- 10 -	25 - - 20—30 -
5. Aug. ...	3 -	- 10—13 -	later only sizes from 20—36 cm.

In view of the fact that neither Marion nor others have observed mature mackerel with flowing spawn in the Mediterranean prior to the month of March, it cannot be regarded as likely that the young fish of 5—6 cm seen on the 22 March (1890) should have been born the same year, though on the other hand they may appear rather small for one-year-old fish. It is possible, however, that the young fish of 5—6 cm observed in May, and the April fish of 4 cm and over, were born in that year, as also, of course, the 2—3 cm fish noted for May. In face of this existing uncertainty in our understanding of the conditions, it is remarkable that Marion should have arrived at the conviction that all smaller forms up to 20 cm belong to the first year of life, i. e. the 0-group. He even considers it probable that the mackerel can attain maturity by the end of their first year of existence.

Returning now to the north-European waters, we lack, to begin with, the sizes immediately adjacent to those young forms taken by the English investigations already mentioned, on the 13. August 1913 in the North Sea. Not till a length of

6 cm and upwards have young mackerel been caught in any great quantity, and here again in Norway, by KNUT DAHL, on the shore at Risör, as I am informed by Dr. HJORT. On 19. July 1905, 311 specimens of these mackerel, then 6—9 cm, were taken in a seine net; these fish, from the sharply defined limitation of their length, seem to form a separate year class:

19. 7. 05 seine net	6	7	8	9 cm.	Total.	Mean.
	5	102	162	42	= 311	7.81 cm.

On the 18. August, similar young fish, in sizes from 6—8 cm were observed in great numbers on the shore at Risör. These little fish were found both in the open water and close in to land, appearing in fairly shallow bays in the openings between the *Zostera* masses, and in some hauls could be taken by the hundred.

The mackerel mentioned by COLLETT, also (Christiania, Vidensk. Selsk. Forh. 1878, No. 1, p. 19) from the 31. 7. 78, length 97—100 mm, seem to belong to this age group; and it is no less remarkable that according to A. W. MALM (1877, p. 409) a shoal of similar small mackerel was observed on the 27. July 1872 on the Swedish coast of the Skagerak, in the Gullmarfjord, near Christineberg. MALM himself noticed on this occasion, how a great mass of little fish — apparently several tons — slipped through the meshes of a seine, so that he was ultimately only able to get the small number of 10 specimens. These were found to be mackerel of 67—100 mm long, and he estimated their age at 13 months. To the fishermen themselves, such little mackerel were entirely unknown, so that their appearance on the Swedish coast was presumably to be regarded as an exceptional occurrence.

From the British coasts I find only a single mention of these sizes: M. DUNN observed, in August and September, at Mevagissey, young mackerel of 7—8 cm which were regarded as first-year fish (the 0-group) (DAY, p. 89).

Young fish of similar size (3 inches long) from the American waters are mentioned by HIND (l. c. p. 14). These are, according to the statements of Newfoundland fishermen, met with about the 20. July on the north coast of the island in the Bay of Notre Dame, and are numerous there in September and October, when the large mackerel are likewise often found. One of the few reliable records of occurrence of young mackerel about the same size is found in the Bulletin of the U. S. Fish Commission vol. XXI for 1901 (1902) p. 27, where G. H. SHERWOOD and Vinal N. EDWARDS mention a few mackerel of 6 to 7.5 cm, taken in a trap on the 9. July at Woods Hole.

Some specimens of this size group, placed in my hands through the agency of Dr. HJORT, had strangely enough, still no scales, and also lacked the silvery sheen; this naturally suggests the possibility that these fish may perhaps not be 13 months old, as MALM supposed, but belong to the 0-group, as with the small specimens already mentioned, of 2 and 4 cm. It might certainly be imagined that these young fish had lost their scales in the process of capture and handling, for, as we know, the scales of the mackerel come away as easily as those of the herring. We have however, testimony from elsewhere to the effect that mackerel of this size still lack scales. CHR. LÜTKEN states (Spolia Atlantica 1880, p. 482) that he found a West

Indian *Scomber colias*, 90 mm long, with colouring fully defined, but altogether naked save for the incipient scale development along the dorsal line, and that in a *Scomber scombrus* of 95 mm he was unable to discern any scale formation whatever. It seems then, that the mackerel really develop no scales during their first summer, but that these do not make their appearance until the following spring. On the other hand it can hardly be doubted that all the young mackerel hitherto noted belong to the so-called 0-group, though it is at least remarkable that the young fish of 2—10 cm are by no means so distributed among the hauls from July to September as to indicate a constant earlier capture of the smaller than of the larger fish. Although the growth during the first summer does not seem to amount to much over 10 cm, this size is nevertheless already represented in the hauls from mid- and end July. It is possible that the larger of the young fish move away from their birthplace in the open sea toward the coast somewhat earlier than do the smaller ones, but these latter are by no means lacking in the hauls made on the coast.

In opposition to the opinion already expressed by me at an earlier date, that the formation of scales does not take place until the second summer of life, commencing probably in the spring, we have the view advanced by Nilsson, to the effect that scale formation occurs as early as the first months of life.

Nilsson claims to prove that the otoliths, the structure of which he describes in detail, but with not very clear illustrations, show that they are formed in the same year as the scales; and he further concludes that since the otoliths are already present even in the larva, and thus formed during the first year of life, then the same must be the case with regard to the scales. I consider, however, that in view of the difficulty of accurately interpreting the structure of the otoliths, it is unquestionably desirable to determine the first one or two years of life of the mackerel, according to the so-called statistical method of C. G. Joh. Petersen, by the greatest possible number of length measurements of specimens belonging to this category. With this object in view, I have been at pains to collect as many as possible of such measurements, though I do not consider this material sufficient for a trustworthy determination of the conditions. I regard it, however, as highly questionable that D. Nilsson should simply ignore those sizes of young fish merely because he had none at his disposal.

The smallest fish he knows — apart from larvæ — measure as much as 120 mm to the base of the caudal fork, and 130 mm to point of tail. In the absence of smaller representatives of the species, D. Nilsson declares this group of fish, the lower limit of which lies about 130, and the mean on 30. August (!) about 162 mm as belonging to the first year-class, or the 0-group [1].

The 0-group fish would then, in the very summer they are born, be furnished already with juvenile scales without growth rings; by the end of September they would be represented by an average size of 195 mm (180 to base of caudal fork)

[1] Nilsson refers to the 1. year-class as the I-group, because the term 0-group appears to him »altogether ill-chosen«. Such a departure from the nomenclature adopted by the International Council for the Investigation of the Sea cannot be admitted, and I naturally could not follow Nilsson's designation.

and by mid-October 218 (200 mm): and these same fish would in the following summer, i. e. the second of their life, measure 280 mm as I-group fish.

On comparing these growth figures with others more credible, we find that cod and haddock, for instance, at the end of their first summer measure only 14 cm and whiting only 12.

It is possible, of course, that the mackerel grows much faster than the species mentioned, but it is hardly likely, and we cannot suppose this to be the case without imperative reason. For the present, no such reason appears to me to have been furnished, and it will probably be even more difficult to find any such, once we have succeeded in capturing young forms of the mackerel of sizes from 2—14 cm in greater quantities, and in determining, by the greatest possible series of measurements, their average sizes for the different months of the year [1].

III. Second and Third-Year Fish (The I- and II-Groups).

Measurements of quite young mackerel for the winter months are altogether wanting, and it is therefore impossible to follow the size and its increase during the first winter by series of measurements. For the spring and early summer months also, no material of young forms is available. The earliest fish I can note as belonging to this category are 4 specimens of American mackerel from Woods Hole, taken 10. July 1906, measuring 12—14, average 13 cm. To these may be added a haul from Risör, by K. Dahl, 16. 8. 05, average size 16.7, and to this again two hauls from 30. 8. and 30. 9. 1911, at Hafstensund, on the west coast of Sweden, by D. Nilsson, average size 15.8 and 18.5 cm. respectively. These captures are shown together with some few others in the table below, where the Nilsson fashion of measurement (to base of caudal fork) has been transposed to give total length (to the tip of the tail).

The smallest fish here shown, 8 specimens from the Dogger Bank (Sept. 1913), measuring 11—16 cm. might perhaps also belong to the 0-group, as none of their scales could be examined, while the 14 specimens from the same locality, taken 17. 10. 21, averaging 17 cm., must, from the presence of scales, be assigned to the I-group. This last also applies to 90 Danish fish, taken in traps, from Espergærde on the Sound (1. 10. 13), average size 18.2 cm, and to 143 specimens from the Kattegat,

[1] A further step towards this aim could in the meantime be made. By chance I have been able recently — 11.—15. October 1922 — on the occasion of a trip with the German investigation steamer »Poseidon« to the Western North Sea, to catch quite a number of young mackerel, which from the date of their capture seem to designate the size at the end of their first summer. Northwest of the Doggerbank and in the so-called »Gat«, I caught a great number of whitings which contained in their mouths or stomachs young mackerel of 8 to 11,5 cm. in length; many of these were in good condition, so as to allow measurements of length, and 32 gave the following series:

cm	8	9	10	11	sum	mean
number	4	13	9	6	32	9.5 + 0.5 = 10.0 cm.

We did not succeed in catching the free swimming mackerel of these sizes and herewith received another proof for the unfitness of our gear in catching these swift fish which, however, are successfully hunted by the whiting surpassing them in size.

between Læsø and Anholt (18. 9. 14), average size 21.7 cm, also 102 specimens from a trawl haul made in the northern part of the North Sea, date unknown, average size 20 cm.

Hauls of second year mackerel.

Locality	Date	11	12	13	14	15	16	17	18	19	20	21	22	23	Total	Average size
Risör	16. 8. 05	—	—	1	2	10	19	17	4	2	—	—	—	—	55	16.7
Hafstensund	30. 8. 11	—	—	—	7	94	93	5	—	—	—	—	—	—	199	15.8
—	30. 9. 11	—	—	—	—	1	21	54	32	78	16	—	—	—	202	18.5
Dogger Bank	9. 13	3	2	2	—	—	1	—	—	—	—	—	—	—	8	13.0
—	17. 10. 21	—	—	1	—	1	4	5	3	—	—	—	—	—	14	17.0
Espergærde (on the Sound)	1. 10. 13	—	—	—	—	—	—	16	30	32	9	3	—	—	90	18.2
Kattegat	18. 9. 14	—	—	—	—	—	—	—	—	6	23	57	52	5	143	21.7
Northern North Sea	?	—	—	—	—	—	2	5	7	32	39	14	1	2	102	20.0

To the same group must evidently be assigned the fish mentioned by Cunningham as taken in November 1891 at Plymouth in sardine nets; specimens of 15—21 cm. Cunningham also (1891—92, p. 230—31) reckons these, in accordance with Dahl's supposition, as belonging to the I-group, thus assuming a similar growth for the mackerel to that I suggest.

The largest fish, shown in the table below (after Cunningham) must probably be assigned to a higher age-class.

Observations of young mackerel, after Cunningham.

Date	Locality	Implement	Length in cm						
30. 9. 91	Plymouth Sound	Hook	13.8						25.6
5. 10. 91	Outside the Sound	—			18.0	21.9	22.6		
3. 11. 91	—	Nets		15.9	19.5				
4. 11. 91	Rame head	—		16.7		20.7			
5. 11. 91	Bigbury Bay	—		15.1		21.0			
16. 11. 91	S of the Eddystone	—			19.8				
23. 11. 91	Rame head	—			17.1	18.5			
10. 6. 91	Outside the Eddystone	Hook					22.3	23.5	26.3

Green (p. 359) and Holt mention this size group from the Irish coast, and the latter indicates them as about 15 cm long.

A similar size group is also recorded from American waters, fish of 12—15 cm long, called »spikes«, and which represent the smallest mackerel of any economical value in the fishing industry. The next larger American trade category, the so-called »blinkers«, belong perhaps to the same year-group, while the somewhat larger »tinkers« up to abt. 23 cm length, should possibly be assigned to the next group in point of age. According to investigations carried out by Marukawa in my laboratory (cf. Ehrenbaum 1912, p. 9) these fish have scales in which only the core is formed, and the winter ring which marks a pause in growth is still lacking.

It therefore seems correct to regard them as a year older than the aforementioned 6—9 cm fish which at the same season of the year had no scales at all.

Nilsson, who has systematically continued these scale investigations, and illustrates his exposition with a series of very good plates, has also described these juvenile scales, but presumes that their formation takes place already in the birth-year of the mackerel, whence the previously quoted series of measurements must all more or less be assigned to the 0-group (which he, as mentioned, calls the I-group). Otherwise, however, Nilsson's age determinations may doubtless be taken as correct, and the results can be made to agree, subject to the allowance of at any case, one additional year.

In order to arrive at mean values for total length of the mackerel in the different years of their life, and especially as regards the higher ages, we should require a far greater number of age-determinations than have been carried out up to now, the more so since among fish of greater age, the sizes of the separate year-classes greatly overlap.

The latest year-class in which this feature is not too greatly marked and which therefore appears in the measurement series as more or less distinct, is the 3. year, i. e. the so-called II-group. In the following survey will be found several series in which this group is well characterised, showing an average of 26, 27, 28 cm for the summer months, and 28, 29 cm for the following winter. In the measurement series for the Helgoland mackerel, captured in July and August, this II-group for instance stands out distinctly with a maximum of 26—28 cm and in exactly the same way among the numerous measurements of the Irish Fishery Board, dealing with mackerel from the Cleggan fishery. In June, July and August of the three years 1901—1903, from 1600 to 2100 of these fish were measured in each case; in the June hauls, the group in question is only poorly represented, but is numerous in July, and in August especially so. For the remaining months of the year, for which also numerous measurements are available, it is altogether lacking. A similar state of things is observed in the case of the Norwegian market fish from Risör, measured by K. Dahl; the group is here still lacking in June among the hauls of spawning fish, but is found in August and also in October, among the larger fish. In the hauls from the Kattegat and the Sound also, besides numerous measurement series of trawl mackerel from the most different parts of the North Sea, this age class is recognisable.

In summer, the representatives of this age group were found to comprise a few isolated fish already mature, the great bulk of the mackerel, however do not reach maturity until the next year, their fourth, i. e. as members of the III-group.

It is also worthy of note that in contrast to many other species, the mackerel shows no essential difference in size between the two sexes; at least, no such difference could be demonstrated after numerous comparative measurements carried out with extensive material.

Sizes of market fish (in cm).

Date	Locality of capture	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	Total
18. 1. 12	N of Viking Bank	—	—	—	—	—	—	7	**30**	17	6	5	7	5	11	7	5	2	5	—	—	—	—	—	1	—	—	—	—	—	—	108
1. 2. 12	Viking Bank	—	—	—	1	—	—	2	**7**	3	3	6	6	12	15	8	13	8	8	3	5	1	—	—	—	—	—	—	—	—	—	101
16. 2. 11	S of Viking Bank	—	—	—	—	—	—	2	**13**	9	9	11	24	28	31	32	18	10	8	2	2	—	1	—	—	—	—	—	—	—	—	200
13. 3. 11	Viking Bank	2	4	2	—	—	—	6	**31**	19	18	23	36	34	16	7	5	4	1	—	—	—	—	—	—	—	—	—	—	—	—	208
1. 4. 11	N North Sea off	—	—	—	—	—	2	4	**19**	18	18	26	37	36	23	12	11	3	1	—	—	—	—	—	—	—	—	—	—	—	—	210
17. 4. 11	Haugesund	1	1	1	1	—	1	4	7	**10**	8	25	46	49	39	24	3	1	—	1	—	—	—	—	—	—	—	—	—	—	—	222
5. 5. 11	N North Sea off Skudesnaes	—	—	—	—	—	—	—	3	**6**	1	2	8	5	7	6	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	40
15. 5. 11	Jutland Bank	—	—	—	—	—	—	2	5	7	7	7	17	12	19	17	9	8	3	2	3	—	—	—	—	—	—	—	—	—	—	118
23. 6. 05	Risör (Spawning fish)	—	—	—	—	—	—	—	—	—	1	3	15	6	2	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	29
29. 6. 04	— —	—	—	—	—	—	—	—	—	—	4	58	82	44	6	4	4	4	2	—	—	—	—	—	2	—	—	—	—	—	—	210
22. 7. 11	Helgoland	—	—	—	—	16	**25**	14	2	11	22	**37**	29	26	10	12	8	—	4	—	—	—	—	—	—	—	—	—	—	—	—	216
27. 7. 11	—	—	—	—	5	17	**66**	39	14	5	30	13	**45**	28	27	5	9	3	1	—	—	—	—	—	—	—	—	—	—	—	—	317
5. 8 11	—	—	—	—	3	6	31	**65**	22	19	36	40	**52**	19	16	9	6	4	—	—	—	—	—	—	—	—	—	—	—	—	—	328
31. 8. 11	—	—	—	—	—	—	6	11	**25**	9	20	16	**50**	40	45	4	16	3	—	—	—	—	—	—	—	—	—	—	—	—	—	248
18. 8. 05	Risör	—	—	—	—	—	4	**12**	8	—	—	—	1	6	4	6	—	—	—	1	—	—	1	—	—	—	—	—	—	—	—	43
18. 8. 11	N of Dogger Bank	—	—	—	—	—	—	—	—	—	1	1	1	11	26	22	16	11	7	6	—	1	—	—	—	—	—	—	—	—	—	103
7. 9. 11	Between Dogger and Oysters	—	—	—	—	—	—	—	—	1	—	1	1	2	5	12	9	9	19	9	7	7	5	5	3	3	2	—	—	—	—	100
11. 9. 13	Christiansand	—	—	1	12	13	27	91	**131**	41	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	322
27. 9.-10. 10. 11	Kattegat	—	—	—	—	1	10	12	**52**	18	16	5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	114
1. 10. 13	Espergærde (Sound)	—	—	—	—	—	6	4	**13**	6	3	3	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	127
4. 10. 05	Risör	1	1	—	—	4	24	68	103	**110**	109	36	8	4	37	64	47	31	19	7	6	3	1	—	4	—	—	2	—	—		689
13. 10. 11	W of N Mud Bank	—	—	—	—	—	—	1	—	2	—	—	3	5	15	23	22	16	6	5	4	—	—	—	—	—	—	—	—	—	—	102
9. 11. 11	Viking Bank	—	—	—	—	—	—	—	—	—	—	—	1	1	3	4	5	14	14	16	24	12	4	2	—	—	—	—	—	—	—	100
22. 11. 11	— —	—	—	—	—	—	—	—	—	1	1	1	9	14	15	8	25	16	10	9	2	—	—	—	—	—	—	—	—	—	—	106
15. 12 11	West North Sea outside Moray F.	—	—	—	—	—	—	—	—	—	1	4	8	17	14	13	14	7	2	2	1	1	—	—	—	—	—	—	—	—	—	84
26. 12. 11	NW of Gr. Fisherbk.	—	—	—	—	—	—	4	**22**	7	10	24	42	28	22	13	9	4	3	2	—	1	—	—	—	—	—	—	—	—	—	191
June 1901 – 03	Cleggan-Fishery	—	—	—	—	2	**11**	3	1	3	35	115	55	13	6	20	73	107	177	255	207	153	145	132	95	71	30	31	12	1	3	1756
July —	West coast of	—	—	—	—	1	4	53	**77**	27	15	29	89	109	48	57	58	91	91	143	159	130	134	126	62	57	12	5	6	—	2	1585
August —	Ireland	—	—	—	—	3	128	**522**	476	145	74	100	106	98	63	64	62	66	55	57	42	27	18	5	1	1	—	—	—	—	—	2113

IV. Food of the mackerel.

The mackerel is undoubtedly one of the greediest of fishes, devouring, apparently, almost everything that comes in its way. Its principal food organisms, however, are probably certain fishes and young forms of fish, as well as a number of crustacea found in shoals, belonging to the families of schizopods, amphipods and copepods.

Among fishes, there are especially some belonging to the herring family which serve as food for the mackerel, in particular young herrings, sardines and sprats — A. W. Malm found in the stomach of a mackerel at Strömstad no fewer than 100 young sprats of 22—28 mm length (25. 7. 65) — besides small sand eels (*Ammodytes tobianus*) and the pelagic young forms of the *Onos* species (*Motella*) which are common in the summer months, and from their glittering silvery coat are often mistaken by fishermen for young mackerel; another, equally incorrect view in regard to these curious little fish has led to their being called »mackerel midges«. They are certainly eaten by the mackerel, but whether they are of any account in its nourishment is doubtful.

Other young fishes however, are also devoured en masse by the mackerel, and the more so, the greater the shoals in which they appear. We find, for instance, in late summer and autumn, young gadoids and especially the young whiting, of the first year, as a great attraction for the mackerel. Young whiting at this age still live very much in the upper water layers, where they are known to consort with the large stinging jelly fish (*Cyanea*); they often move down, however, into deeper water, and near the bottom, giving rise to enormous concourse of mackerel there, which are then taken in hosts by the trawl.

It is very noteworthy that the mackerel have also some cannibalistic tendency, occasionally devouring their own kin. According to information furnished by Cand. Alf. Dannevig (Norsk Fiskeritidende 1917, p. 122) he found at Korshavn, in summer, on examining the stomachs of 65 mackerel taken on the hook, not only small herrings and sand eels, but also young mackerel, and these, moreover, of 120, 95, 67, 64 and 62 mm. I have myself observed that mackerel even in the larval stages will eat their fellows. Though the food of the larvæ consists mostly of smaller plankton forms, e. g. ova, nauplii and adult specimens of the copepod species *Temora longicornis*, and *Calanus*, as also *Podon* and *Evadne*, as stated by M. V. Lebour (1918, p. 439, and 1920, p. 305) there were, however, in a few cases, whole and still distinctly recognisable mackerel larvæ visible in the interior of the larva's stomach. M. V. Lebour includes also *Trachinus vipera* and *Blennius* among the food of mackerel larvæ.

Of crustaceans, the food forms of most importance to the mackerel are numerous copepod species, *Cladocera (Podon, Evadne)*, also representatives of the schizopod genera *Thysanoessa* (*neglecta* Kr.) and *Nyctiphanes* (*norvegica* M. Sars), *Rhoda-Boreophausia* (*inermis* Kr.) and various species of *Mysis*. M. Dunn, for instance, as stated by G. E. Bullen (1912, p. 396) saw from the harbour pier at Newlyn, small shoals of mackerel, numbering 20 to 30 fish, in company with horse mackerel (*Caranx*) chasing the mysids which swarmed in the water. These were the *Macropsis slabberi*

van Beneden, a form characteristic of the brackish waters of the North Sea coasts, and occasionally met with in dense shoals. Amphipods also are often eaten, especially such as now and then occur in numbers in the upper water layers, as for instance the *Euthemisto* and *Parathemisto* species, *Caprella* etc. also numerous larval forms of higher and lower crustaceans.

Of less importance are certain *Appendiculariae,* as well as molluscs of the species *Clione* and *Spirialis retroversa.* Cephalopods also, and especially small or juvenile forms, are eaten at times by the mackerel; the Irish investigators repeatedly found a *Sepiola* species; my assistant N. Peters found in trawl mackerel from the NW-corner of the Dogger Bank in October 1921 some young specimens of *Loligo vulgaris* Lam. and of these as many as 3 in the stomach of a single fish. A. W. Malm found in July, at several spots on the Swedish Skagerak coast, repeated occurrences of *Chaetopoda* for instance *Nereis longissima* (Johnst.) in the stomach of mackerel, and A. Scott (1914, p. 25) mentions *Tomopteris.*

Medusæ also are occasionally devoured; Möbius and Heincke explain the attacks of mackerel upon these by suggesting that they endeavour to draw out the *Hyperia* from the parenchyme. M. Dunn, of Mevagissey, however, has stated that the mackerel occasionally eat small dark green medusæ of the size of a split pea, and A. Scott (p. 23) observed that the ctenophores especially *Pleurobrachia*, and in smaller numbers also *Beröe,* which were represented in enormous quantities in the plankton on the coast of Lancashire in July, are devoured in great numbers by the mackerel, whose stomachs were often literally full of them. In the Mediterranean, numerous »swimming bells« of siphonophores have occasionally been found in the stomachs of mackerel. A. Scott (1914, pl. I) also gives illustrations of copepod and decapod larvæ from the stomach-contents of mackerel.

A very great number of stomach-content investigations have been made with mackerel from the Irish waters, and some of the most important observations here made are published by G. P. Farran in the Irish Fishery Reports (1904, p. 17). According to these, the mackerel's principal food in the waters referred to, during the first half of the year, from Febr.—July inclusive, consists of copepods, and these of several different species, the greatest quantities, however, falling to *Calanus finmarchicus* (Gunn.) and next in order, *Metridia lucens* (Boeck). Besides copepods, they eat at times, in varying quantity, also schizopods (*Thysanoessa*), decapod larvæ (*Galathea*) and pteropods (*Spirialis*), then, from July onwards, but especially in August, a fish diet predominates, sand eels (*Ammodytes*) forming the principal component here. A very peculiar point is the fact that we frequently, though not always, find the various items of food, copepods, *Spirialis*, *Ammodytes*, in separate layers in the stomach; this Farran explains as indicating that the fish must have swum through shoals of the mentioned organisms one after another.

These statements given by Farran are notably supplemented by the data of the observation journals of the Irish Fishery Board, placed at my disposal by E. W. L. Holt, and dealing with an enormous number of food investigations during the years 1901—1904. Arranged in order of months, we find the following[1]:

[1] The principal articles of food are set first and spaced out.

In February, the stomachs of Irish mackerel were found to contain chiefly schizopods, also remains of fish, copepods (chiefly *Metridia lucens* and *Pseudocalanus elongatus*), amphipods, appendicularians and chaetopods.

In March: Schizopods (especially *Nyctiphanes* and *Thysanoessa*) besides remains of fish (*Ammodytes*), amphipods (*Parathemisto*) and *Sepiola*.

In April: Copepods (especially *Calanus finmarchicus* and *Pseudocalanus*), schizopods (as above), remains of fish (*Ammodytes*), amphipods, cirripedian larvæ, gastropod larvæ, *Spirialis*, *Sepiola*, fish eggs, chaetopods.

In May: Copepods (*Calanus*, *Temora*, *Pseudocalanus*, *Metridia*), schizopods (as above), fish remains (*Ammodytes*), decapod larvæ, amphipods, cirripedian larvæ, *Spirialis*, *Clione*, fish eggs.

In June: Copepods (as above), decapod larvæ (*Zöea* and *Megalopa*), fish residue (*Ammodytes* and occasional young *Motella*), schizopods, amphipods, *Spirialis*.

In July: Copepods (mostly *Pseudocalanus elongatus*), *Zöea* (*Porcellana*, *Galathea*), amphipods, (*Hyperidae*), fish remains (*Ammodytes* and gadoids), *Spirialis*, *Clione*, schizopods, *Cladocera*, (*Podon*, *Evadne*).

In August: Fishes (small gadoids, clupeids, especially sprats, *Ammodytes*), copepods (*Calanus finmarchicus*), young schizopods, *Zöea*, (*Porcellana*), *Phyllosoma*, *Cladocera* (*Podon*, *Evadne*), *Spirialis*, *Clione*, *Diphyes*.

In September: Fish (sprats), copepods, appendicularians, amphipods, crustacean larvæ.

In October, November› December: sprats and *Ammodytes* are still found in the stomach, as also schizopods (*Thysanoessa*), amphipods (*Parathemisto*) and copepods, but in the great majority of cases the stomach was empty, or contained only a mass of slime.

In Plymouth also, the food of the mackerel has been made the subject of special investigation, described by G. E. Bullen (1908, p. 269) in the form of plankton studies. The material is derived from the western part of the English Channel, and from the Bristol Channel, and was collected during the months of April, May and June (1906—1907). The food consumed consisted for the most part of plankton, and this both vegetable and — especially — animal forms; not until an advanced season of the year is the plankton gradually displaced by young fish and specimens of *Crystallogobius Nilssoni* v. Düb et Kor. The taking of these last, not properly planktonic organisms generally seems to indicate an approaching breaking up of the mackerel shoals.

Among the animal forms of plankton organisms devoured as food the most important are the copepods, and of these again the species *Calanus finmarchicus*, *Pseudocalanus elongatus* and *Temora longicornis*, thereafter *Acartia clausi*, *Centropages typicus*, *Metridia lucens* and *Paracalanus parvus*. Besides these, the following are of great importance; *Zöea* larvæ, *Sagitta bipunctata* and *Oikopleura dioica; Spirialis retroversa* is also named. Not infrequently also, distinctly recognisable remains of phytoplankton are found in the stomachs, the predominant item here being *Phæocystis globosa* Scherffel, which is widely distributed during the months of spring.

It seems, however, as if the mackerel always give preference to the zooplankton, the best hauls being made when this was greatly predominant over the vegetable forms.

Some mackerel taken (24. March 1907) in trawl nets on the mackerel grounds at Start Point, discovered by the French, had also mostly copepods in the stomach, principally *Temora longicornis;* also vegetable forms were found, however, especially some diatoms and *Phæocystis globosa*, and in the stomachs containing mostly phytoplankton, especially *Oikopleura dioica.* It should here be pointed out however — and Cligny also draws attention to the fact — that both the mackerel stomachs and the plankton samples from Start Point ground, investigated by Bullen, date from the spring, and not from a season when the mackerel were abundant there, as in winter, or earliest in October.

According to Bullen, the English mackerel fishermen take the colour of the water as an indication of their prospects for good or poor results. Green and blue water they regard as favourable, but especially yellow. The origin of these colours has not been determined with certainty; it is likely, however, that it depends directly or indirectly upon the presence of certain plankton organisms. The yellow water, for instance, is, according to a letter from Bullen to »Nature«, dated 24. 7. 1913, indebted for its colour to the presence of numerous calanids (*Calanus finmarchicus*, *Pseudocalanus elongatus* etc). (Cf. also XXVIIth ann. rep. Marine Biolog. Station at Port Erin, Liverpool 1913, p. 32—36).

E. J. Allen (1909, p. 394) has found a peculiar formula for the relation between a good catch of mackerel and a rich development of the plankton. The abundance of copepods, which of course form the principal food of the mackerel, depends on a rich development of their food organisms, to wit, diatoms and peridineans, and one of the factors favourably affecting the development of the latter is light; Allen therefore endeavoured to build up a relation between the amount of sunshine in February—March and the extent of the mackerel hauls in May. One is, however, reluctant to attach great weight to the results of these investigations, as no similar relation could be demonstrated between the amount of sunshine in April and May, and the mean temperature of the water in the months from February to May.

With regard to the stomach contents of mackerel taken in the North Sea region, I have myself made some investigations here. Mackerel taken in summer off Helgoland with trolling lines (norweg. dorge), had in their stomachs numerous larger plankton forms, e. g. larvæ of the higher *Crustacea*, copepods, *Cladocera*, *Chaetopoda*, as also smaller plankton forms down to *Ceratia*; amphipods were also occasionally observed, e. g. *Caprella* and *Proto ventricosa*, which were numerous among the plankton at the same time. In midsummer and early autumn, fish food takes the lead, and of this chiefly *Ammodytes* and young herring. The former were especially frequent in the stomachs, mostly several (2 or 3) specimens at a time. Sand eels and young herring often attract the mackerel to the immediate vicinity of the sandy shores of the Frisian islands, where they are then also caught in shore seines. In the summer of 1905, the whole shore of the North Frisian Islands, especially Sylt, was covered with young herrings, which were pursued by the mackerel right up into the breakers, and then flung on shore by the waves.

Of more interest, perhaps, are the stomach investigations of North Sea trawl mackerel, carried out in my laboratory, with the assistance of H. Marukawa, the fish being mostly from the fish market in Hamburg. In these investigations 100 mackerel at a time were examined about twice a month at all seasons of the year, only a few of the fish however, in each case being found with full stomachs. During the period from January to early May, these samples were throughout derived from the slope of the northern North Sea towards the Deep Norwegian Channel, and mostly from the Viking Bank, which is evidently a favourite winter resort with these fish. The stomachs contained chiefly schizopods, often in very great numbers, and even *Meganyctiphanes norvegica*, *Thysanoessa neglecta* and *longicaudata*, and *Rhoda inermis*; further, of amphipods numerous *Parathemisto oblivia* and occasionally copepods, among which in one case abt. 150 large specimens of *Euchaeta norvegica* were recognisable; on some few occasions fish remains were also discernible, scales and bones; as isolated instances, 2 young *Ammodytes* and 1 young herring were found.

The mackerel examined during the period from May to end September came from the Great Fisher Bank, the Jutland Bank, the Dogger and the southern Mud Bank. Stomach contents were mostly much digested and difficult to determine, in a few cases, however, it was possible to discern copepods (*Temora*, *Pseudocalanus*, *Centropages*, *Calanus*, *Acartia*), portions of schizopods, amphipods (*Apherusa*) larvæ of decapods and *Cirripedia* (*Balanus*); remains of fish (*Ammodytes*) were present in varying quantity, but in the September hauls, from waters south and east of the Dogger, we often found from 1—3 young herrings of 10—13 cm length in the stomachs, and in September 1921, when very large catches of mackerel were made with the trawl on the Fladen ground, the stomachs of the fish were found to be stuffed full of small gadoids (especially whiting) which abounded on the fishing grounds at the time, a proof that the mackerel seek the deeper water layers not only for their winter rest, but also in search of food, and especially in late summer, when driven by increased need of nourishment, to change their former plankton diet for one of fish. Whiting are especially calculated then to lead their pursuers into deeper water layers, as they spend their time at this season alternating between the upper and lower strata, often in company with stinging jelly fish (*Cyanea*) near the surface and between whiles also living on the bottom.

In October also the mackerel were found on the same fishing grounds. Other trawl-hauls from October to end December again, came from the northern part of the North Sea, e. g. Viking Bank, and the area west and north of the Great Fisher Bank. In these fish, no stomach content was discernible beyond a little sandy and slimy mass.

The investigations published in 1914 by D. Nilsson, dealing with mackerel from the Swedish coasts of the Skagerak and Kattegat also contain numerous notes as to what was found in the stomach investigations. This writer increases the list of food organisms by the young forms of some prawn species, to wit *Pandalus borealis* Kr. and *Pasiphae tarda* Kr.; and he comes, unlike most other writers, to the conclusion that the mackerel feed essentially — during their stay in the Swedish

waters — on small Plankton only, and do not eat more fish in autumn than in spring and summer.

With regard to the food of the Mediterranean mackerel, French writers such as A. F. Marion and P. Gourret, have furnished information. According to these writers, the principal article of food both for large and small mackerel consists of the different developmental stages of clupeids, especially pilchards, and also silversides (*Atherina*) which occur in great shoals near the coast, finding their own food, again, in the dense clouds of copepods. The copèpods, however (*Temora, Dias, Calanus*), and the numerous developmental stages of the higher *Crustacea* (*Zöea* etc.) are also eaten by the mackerel themselves, especially by the younger fish. Mackerel taken in the nets are not infrequently found with a half-swallowed sardine sticking out of the mouth. Besides the clupeids, which constitute at any rate the principal article of food, the following may also be mentioned as occasionally found among the stomach contents: *Argentina sphyræna*, *Gobius sp.*, *Palæmon* and also the swimming bells of siphonophores (*Diphyes*) already noted.

Interesting information is also furnished by Br. Goode (Hist. of the mackerel fishery, p. 105) regarding the food of the American mackerel. This greatly resembles that of the European form. The leading place is occupied by various species of *Crustacea*, in larval and fullgrown forms, as also a series of fishes, small molluscs, especially *Pteropoda* and even jelly fish. Among the crustaceans, the larvæ of various species of crabs and hermit crabs are mentioned, also copepods and especially schizopods. Of the latter, the species belonging to the genus *Thysanopoda* and related forms seem, as in European waters, to play an especially important part. These and the copepods probably constitute the form of fish food called by the American fishermen »shrimp« and »red seed«, with which the mackerel are often stuffed to such a degree as to spoil the fish, giving rise to the measure of hanging them overside in a net bag to keep them alive until the food is digested — as the Norwegians do with herrings and sprats taken in the huge land seines (staengs). Of fish which serve as food the following are mentioned: herring, anchovy (*Engraulis*), sand eel (*Ammodytes*), smelt (*Osmerus*), hake (*Merluccius* or *Phycis*), silverside (*Atherina*), barracouda (*Sphyræna*) etc. Even the young of their own species are not despised as food.

Professor Verrill, in his »Vertebrated animals of Vineyard Sound« notes the stomach contents of mackerel taken 18. July 20 miles south of No Man's Land; they contained *Thysanopoda* spec., larvæ of short and long-tailed crustacea, young hermit crabs, *Platyonichus ocellatus*, many copepods, and numerous shells of the Pteropod *Spirialis gouldi*. The last named appear to play an especially important part. Rathbun also, in the Bulletin of the U. S. Fish Commission vol. VII 1887 (Washington 1889, p. 266-9) reports on the stomach contents of mackerel taken 10. and 13. 5. at abt. 38° N 74° W. Some contained dense purple masses of *Themisto bispinosa*, also many copepods, especially *Temora longicaudata*, *Pleuromma spec.* and *Calanus spec.* besides some rarer forms; also many *Sagitta* and *Spirialis spec.*

According to Hind, in St. Lawrence Bay at certain times of the year, sand eels are a particularly great attraction to the mackerel.

In a recent paper (1912, p. 394) BULLEN also deals with the manner of feeding among the mackerel, when living on plankton. In this, he starts from the supposition that plankton-eating fish, and among them the mackerel, at certain times swallow the plankton as a whole, without making any selection; and he declares that the mackerel, as also herrings and others, could live for a long time on plankton, choosing first the larger organisms, but taking also smaller forms when these are present in sufficient quantity. This choice of food naturally leads the mackerel to localities where the organisms in question, i. e. the zooplankton, are to be found; and the movement of mackerel in towards the coast must be regarded as due to the composition of the plankton in the coastal waters at the time.

I have expressed the view, also in a letter to BULLEN, that mackerel, when living on plankton, always make a selection. The idea that mackerel filter the plankton through the straining apparatus of their gills and then swallow it, or even perhaps, as Ambrose has declared, swim about open-mouthed in the water to gulp down the plankton, is undoubtedly erroneous. The filter of the gills serves to keep the rough and prickly parts of the plankton drawn in with the breathing water, away from the delicate laminae of the gills which might otherwise be damaged; not to collect it as food. Moreover, plankton found in the stomach of a mackerel never appears in its original composition but invariably as a selection, which can certainly be made in very different ways. Some confirmation of this view is, I think, to be found in BULLEN'S observation of the fact that the stomach of the mackerel at certain times, when the fish are living on phytoplankton, appears thick walled and contracted, while at others, when the food consists of zooplankton, it is thin-walled and greatly expanded. In the latter case, the stomach could be greatly inflated by air, but not in the former.

V. Enemies of the Mackerel.

A fish appearing in such enormous shoals as does the mackerel naturally suffers much from the persecution of enemies. In many places indeed, these enemies are so numerous as to cause great damage to the fish taken by the fishermen. The yield of the Irish spring fishery, for instance, is in many years greatly affected by the appearance en masse of a species of shark. Of these HOLT reckons the picked dogfish (*Acanthias vulgaris* Risso) as the most deadly. HOLT informed me that these robbers are never lacking, but often occur in gigantic numbers, when they snap at every fish caught in the meshes of the net; they are not able to catch a mackerel swimming at liberty. The porbeagle also (*Isurus cornubicus* Gmel) and the tope (*Galeus vulgaris* Flem.) are nearly always on the spot, and towards the end of the fishing season, the blue shark (*Carcharias glaucus* L.) often appears in great numbers, but generally too late to do much damage. Occasionally also, a basking shark (*Selache maxima* Gunn) about 40 ft. long is found in the nets, but without its presence becoming noticeable among the fish.

Towards the close of the 90's, it seemed to Holt that the spring fishery at Valentia, Co.-Kerry, would have to be given up, as enormous shoals of larvæ of *Corymorpha nutans* stopped up the nets and probably damaged the mouths of the fish as well. J. Couch mentions (1877, p. 76) that great damage is caused to the mackerel at times by a species of swimming crab — *Polybius Henslowi* — which manages to fix itself into the fish by means of its sharp nippers; also by the sea lamprey (*Petromyzon marinus* L.).

Br. Goode cites among the enemies of the mackerel first and foremost the solan goose (*Sula bassana*) which often feeds voraciously on mackerel, also dolphins, whales and the mackerel sharks (*Isurus dekayi* Gill and *I. cornubicus* Gmel) and picked dogfish (*Acanthias*); the latter often bite through the purse seines in which the mackerel are caught. There is also a series of other predatory fish which prey upon the mackerel, among which the blue fish (*Pomatomus saltatrix*) is especially noted. Its appearance on the fishing grounds generally frightens the fish away at once, and soon puts an end to the fishery. The same applies to the tunnies, pelamides and related forms in the warmer seas, e. g. the Mediterranean. The appearance of the tunny here largely depends upon the shoals of mackerel which they follow, and on the other hand it is maintained that the yield of the mackerel fishery is not infrequently reduced to a loss when the shoals of mackerel have been too seriously thinned out by the tunny.

Very noteworthy is the statement of Prof. Verrill as to the way the cuttlefish (*Illex illecebrosus* Lesueur) which is of very frequent occurrence in the Atlantic waters, pursues the young mackerel of 10—15 cm length. It darts with lightning speed at the mackerel swimming by, and kills them with a single bite in the neck, cutting out a triangular piece of flesh, and penetrating down to the marrow. The attack upon the mackerel is not always immediately successful, but will then be several times repeated (cf. Brown Goode l. c. p. 18, cf. also 3rd Ann. Rep. Fish Board of Scotland 1885 app. p. 67).

Dr. R. Gast observed in the Adriatic, as he informed me, that the *Loligo* which occur there in great shoals behave in precisely the same manner towards the Mediterranean mackerel, and thus often cause great damage.

EXPLANATION OF TEXTFIGURES.

Larvæ and young forms of *Scomber scombrus* L.

Fig. 1. Larva, 5 mm long, taken 7. July 1903, 30 miles NW of Helgoland.
Fig. 2. Larva, 7.2 mm long, taken 7. July 1903, 30 miles NW of Helgoland.
Fig. 3. Larva, 8,6 mm long, taken 27. June 1905, English Channel. Johs. Schmidt lgt.
Fig. 4. Larva, 13.2 mm long, taken 2. August 1904, Risör. K. Dahl lgt.
Fig. 5. Young fish, 16 mm long, taken 27. July 1906, Skagerak. Johs. Schmidt lgt.
Fig. 6. Young fish, 19 mm long, taken 2. August 1904, Risör. K. Dahl lgt.
Fig. 7. Young fish, 43 mm long, taken 19. July 1905, Risör. K. Dahl lgt.

Figs. 1—3 and 5 drawn by E. MOHR from balsam preparations.
Figs. 4 and 6—7 drawn by H. VARGES from alcohol preparations.

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Résumé.

I. **Conditions du frai.** La grandeur des oeufs du maquereau varie de 1.0 à 1.38 mm; dans la partie méridionale de la Mer du Nord le diamètre moyen des oeufs diminue de 1.276 (fin mai) à 1.10 (mi-juillet). La boule d'huile mesure de 0.28 à 0.35 mm. Les oeufs des maquereaux de l'Amérique sont à peu près de la même taille, ceux des maquereaux de la Méditerranée sont probablement plus petits, mais ils ne sont pas encore suffisamment connus et ne se laissent pas distinguer de ceux du *Scomber colias*. L'embryon à l'état très développé ainsi que la larve qui en sort possèdent outre un pigment noir un autre de couleur vert mousse (jaune tirant sur le brun à la lumière réfléchie) réparti d'une manière très caractéristique.

Dans le but de frayer les poissons matures semblent chercher les eaux plutôt profondes.

Un degré de salinité déterminé n'est point demandé pour le dépot des oeufs, cependant une salinité de 26 $^0/_{00}$ est considéré comme le minimum.

La saison du frai montre dans les mers septentrionales une grande conformité; la saison principale dure de la fin de mai jusqu'à la fin de juillet; le maquereau de la Méditerranée, cependant, fraie surtout aux mois de mars et d'avril.

Grâce à des recherches quantitatives on a constaté que les oeufs du maquereau se trouvent en quantités plus ou moins grandes dans toutes les parties de la Mer du Nord et du Skagerrak; cependant, il paraît que les oeufs se rencontrent en plus grande abondance dans la partie orientale de la Mer du Nord et le Skagerrak que dans la partie occidentale de la Mer du Nord.

II. **Larves et maquereaux immatures.** Une description et des réproductions d'exemplaires de 5, 7.2, 8.6, 13.2, 16, 19 et de 43 mm complétent nos connaissances sur les différents stades de développement.

Avec les engins de pêche ordinairement employés on ne réussit guère ou point du tout à pêcher des petits poissons de plus de 14 mm de longueur, car grâce à leur vitesse les plus grands évitent les filets; la pêche des poissons de stades plus grands se fait le mieux en eau calme à l'aide de filets à main ou, de nuit, à la lumière d'une lanterne.

Les larves se rencontrent surtout dans les couches d'eau supérieures.

Des jeunes poissons de 3 à 11 cm de longueur ont été rencontrés dans les fjords de la Norvêge et une fois au milieu de la Mer du Nord; des jeunes

poissons de ces stades se sont également rencontrés sur les côtes de l'Amérique et surtout dans la Méditerranée. Récemment on en a trouvé dans l'estomac du merlan.

Ces stades appartiennent à la première année ou au groupe 0, et comme ils n'ont pas encore d'écailles, ces dernières ne se développent évidemment qu'après la fin du premier été.

III. Au moyen de mesures de longueur on peut encore déterminer avec quelque certitude ceux qui appartiennent aux groupes I et II. Vers la fin du deuxième été la longueur moyenne en est de 20 à 22 cm, pendant le troisième été elle est de 27 à 28 cm. Cependant, pour en déterminer d'une manière plus précise la croissance au cours desdites années et des années suivantes les recherches nécessaires sur leur âge nous manquent encore.

IV. **La nourriture du maquereau** consiste, au printemps, notamment en différentes variétés de plankton, surtout en copépodes, schizopodes, amphipodes et larves de décapodes, de plus de ptéropodes; après la saison du frai et en automne elle consiste principalement en poissons, surtout en jeunes clupéides, gadides, ammodytes etc.

V. Parmi les **ennemis du maquereau** se trouvent en premier lieu quelques poissons du genre des squales, tels que *l'Acanthias* et le *Lamna*, en outre le pomatome »(américc. bluefish)«, le thon, quelques genres des sèches (*Illex* et *Loligo*), de plus les oiseaux de mer (*Sula*), les dauphins, les baleines.